Eocene

by

L. Gidai and J. Haas

Eocene formations make up the unit of highest morphological position of the hill range extending to the east of Sümeg, the Rendeki-hegy, and, in addition, they crop out in a number of minor patches, too. The sequence was exposed by a lot of exploratory boreholes. All these results have provided possibilities for the clarification of some stratigraphic problems that have been problematic for a long time. The Eocene sequence of the horst block of Sümeg presents the general geological features typical of the western part of the Transdanubian Central Range. Type section of several proposed lithostratigraphic unit occur within the study area.

Exploration history

The monograph of J. Böckh (1874) is the first among the summarizing accounts of the Bakony's Eocene to mention the Eocene formations from the Sümeg area. He distinguished two sequences within the Eocene: the "Nummulites limestone" at the base and the "Orbitoidea-rich calcareous marl" at the top.

M. Hantken (1875) singled out, upon his elaboration of the larger Foraminifera of the southern Bakony Mountains, three horizons:

1. the "*Nummulites Tchihatsheffi*" (= *N. millecaput*) Beds
2. the "*Nummulites spira*" (*Assilina spira*) Beds and
3. the "*Nummulites laevigatus*" Beds

R. Hojnos (1943) divided the Eocene sequence of the immediate vicinity of Sümeg into two parts. The lower part, the Main Nummulites Limestone, was assigned by him to the Parisian-Bartonian, The upper one, the marly Orthophragmina Limestone, to the Priabonian.

E. Szőts (1956), in his summarizing work, discussed the Bakony dividing it into 8 subareas. One of these is the Sümeg–Csabrendek subarea presenting the following sequence:

"Nummulites-Orthophragmina limestone and marl"	— Lutetian
"Main Nummulites Limestone"	— Lutetian
"Nummulites-Miliolina Limestone"	— Londonian

E. Szőts' treatise gave, in addition to a stratigraphic synthesis, a paleogeographic interpretation as well.

G. Kopek and T. Kecskeméti (1960) singled out 7 horizons within the marine Eocene of the Bakony. The lowermost horizon, the *Nummulites laevigatus* Horizon, was placed in the Ypresian, the rest, mainly upon evaluation of the larger Foraminifera, was assigned to the Lutetian stage. In the Sümeg area they supposed the presence of an unconformity between the Lower and Middle Eocene and they identified this with the overall unconformity supposed to exist throughout the eastern part of the Bakony Mountains.

In a summarizing paper, G. Kopek, T. Kecskeméti and E. Dudich (1966) registered 16 horizons of the Eocene in the Transdanubian Central Range. In their tabulation they listed, within the Sümeg–Darvastó–Nyírád subarea, the following horizons:

XIII. Glauconite Horizon (the uppermost horizon of the Middle Eocene)
XII. *N. millecaput* Horizon
XI. *N. striatus* Horizon
X. *N. perforatus* Horizon (marker horizon–Upper Lutetian)
IX. *Assilina spira* Horizon
(VIII. to II. intra-Lutetian denudation)
I. *Alveolina oblonga* Horizon (Lower Eocene)

In their paper published in 1971, the afore-mentioned authors revised, for the southern Bakony, their statement concerning the "intra-Lutetian denudation" and took the Lower to Middle Eocene transition to be continuous.

M. Jámbor-Kness (1971), after studying the larger Foraminifera from the borehole Nagytárkány (Nt) No. 1103 put down in the vicinity of the Sümeg area, pointed out the presence of a continuous sequence from the Lower Eocene up to the end of the Middle Eocene, refuting thereby the existence of an intra-Lutetian denudation.

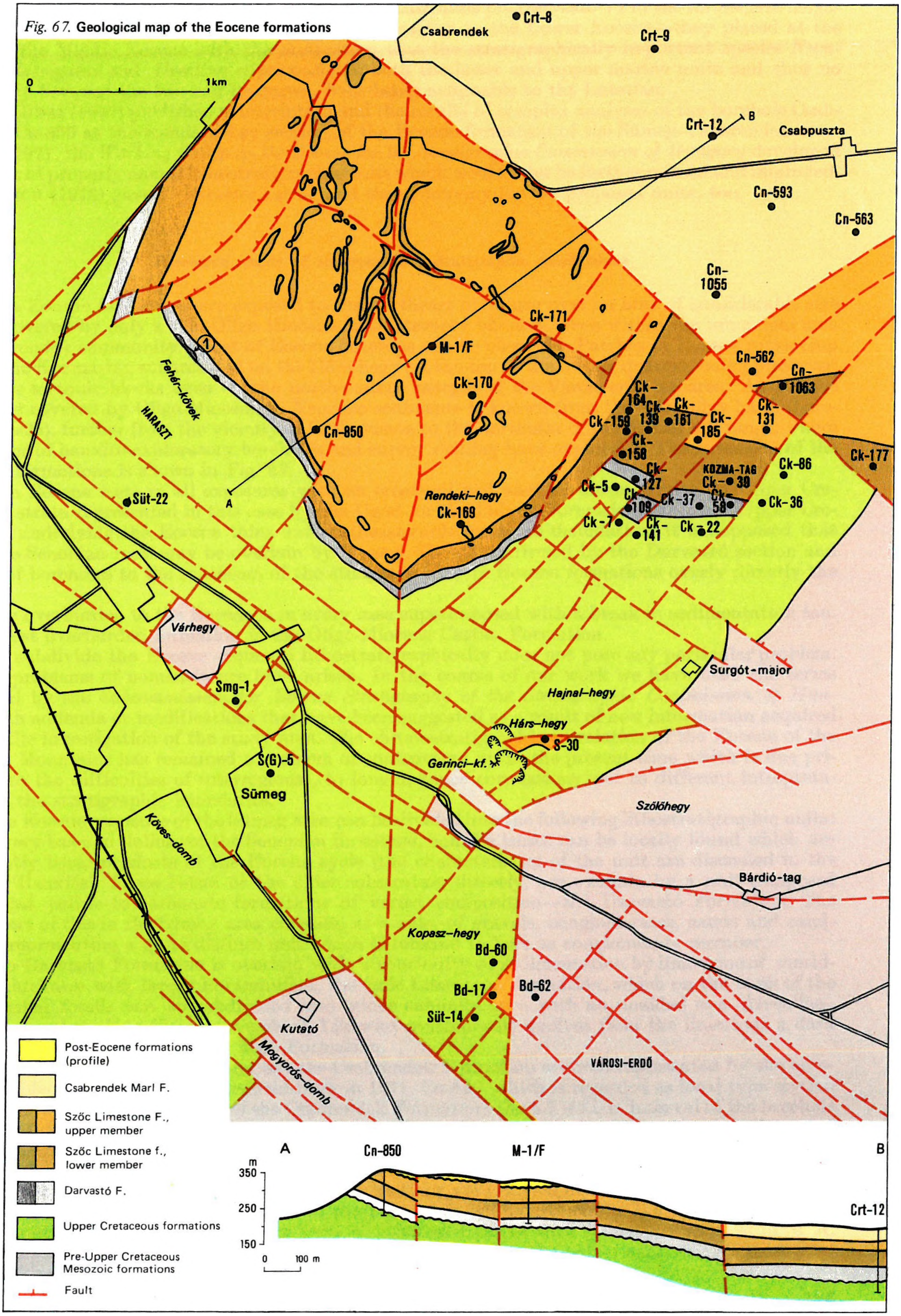


Fig. 67. **Geological map of the Eocene formations**

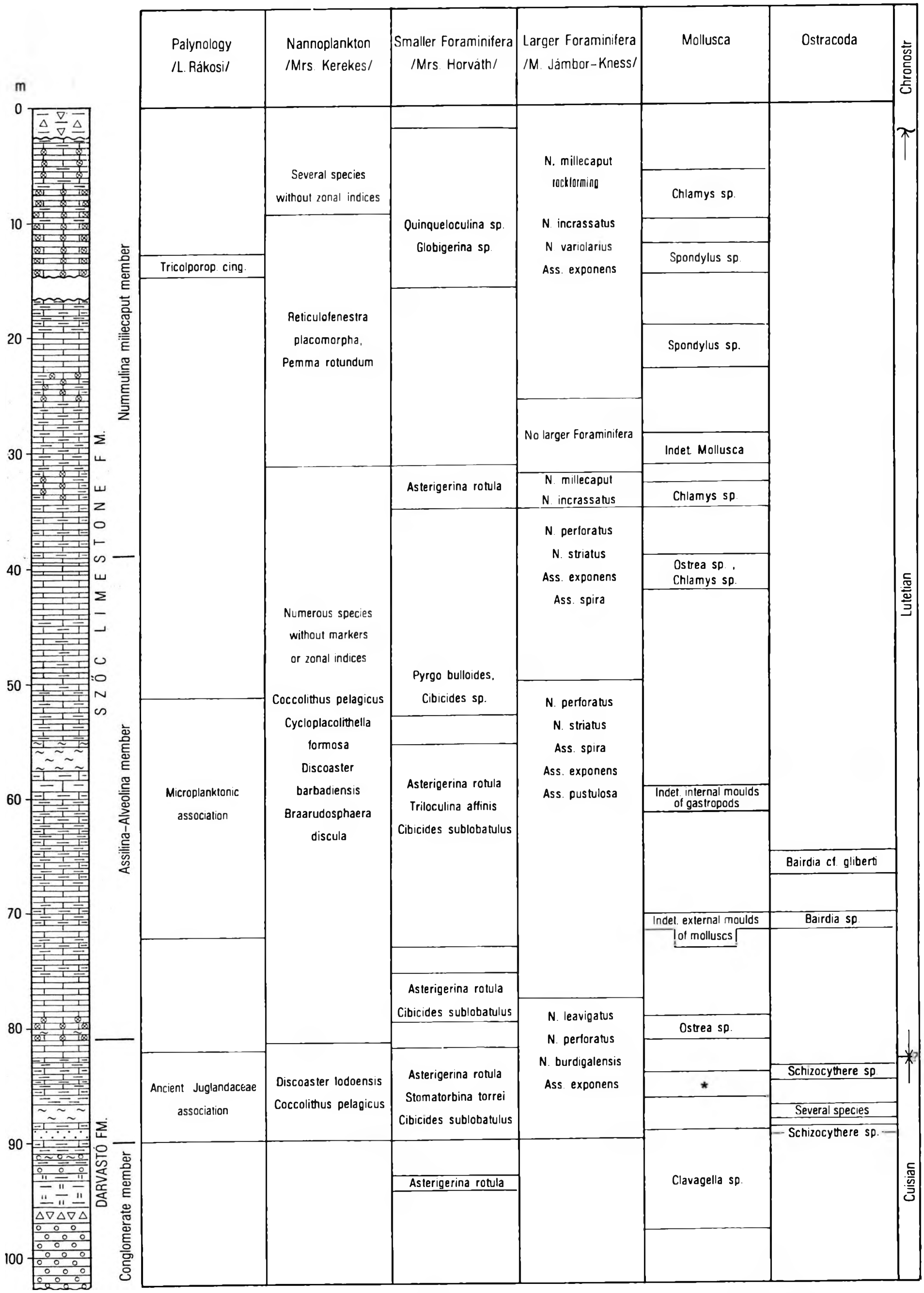


Fig. 68. Lithologic log and stratigraphic record of the borehole Csabrendek Cn-850

* Corbula exarata, Natica sp., Ampullina cf. perusta, Lima sp., Cardium sp., Spondylus sp.

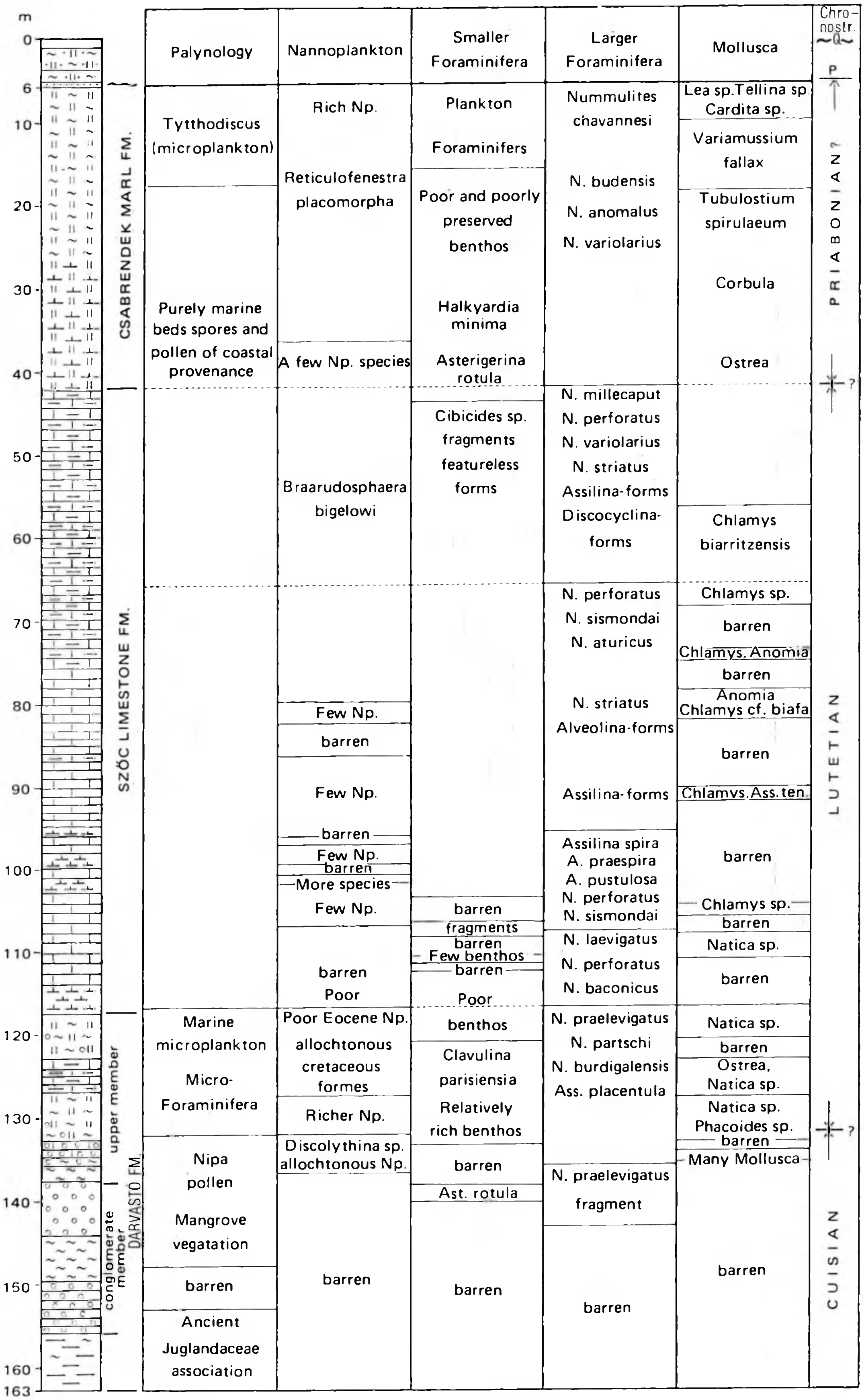


Fig. 69. Lithologic log, stratigraphic record and fossil content of the borehole Crt-12: a review

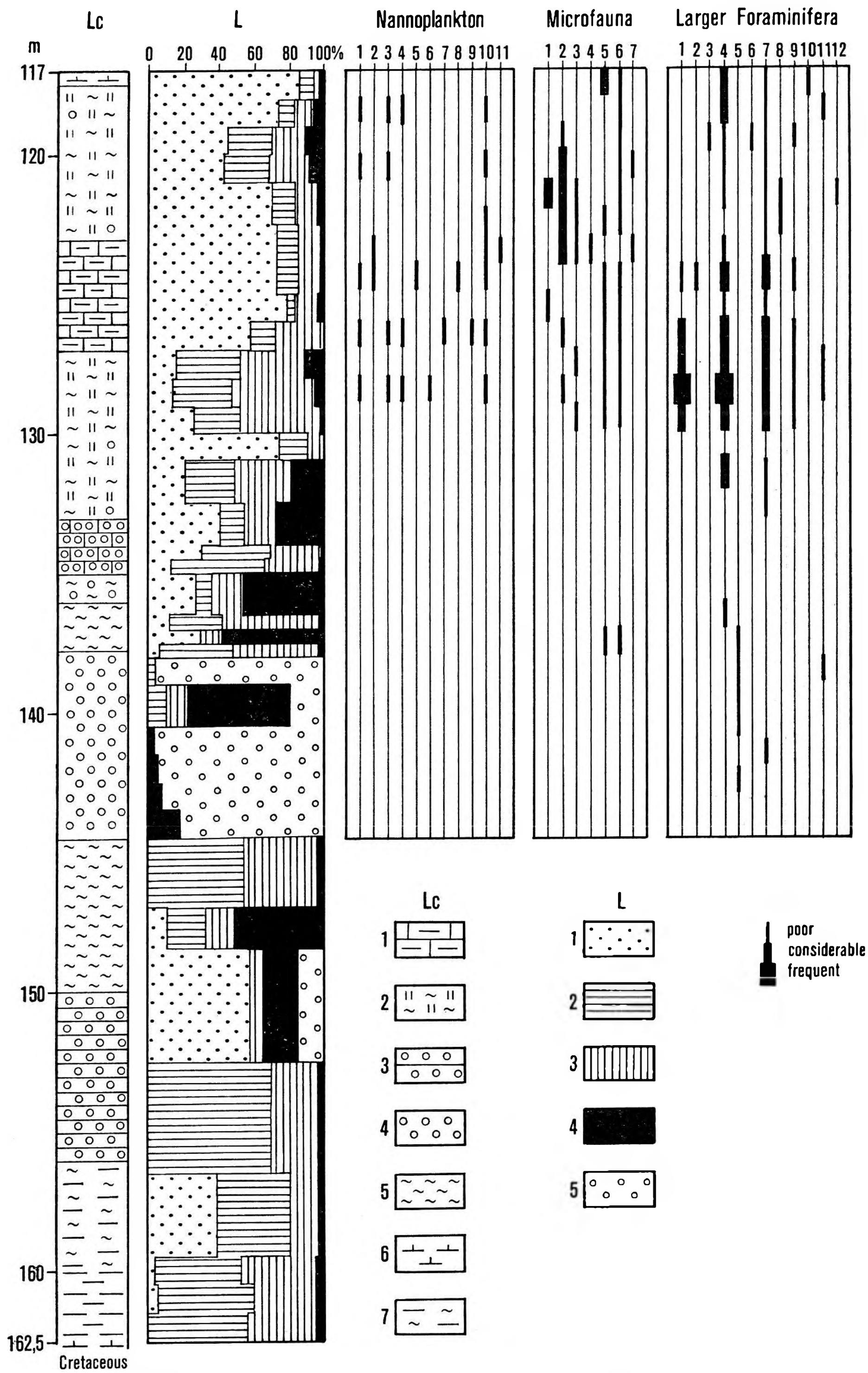


Fig. 70. The Darvastó Formation interval of the borehole Crt-12: lithologic column and analytical record

Lithologic column (Lc): 1. argillaceous limestone, 2. silty marl, 3. conglomerate, 4. gravel, 5. marl, 6. calcareous marl, 7. argillaceous marl. — ***Lithologic composition*** (L): 1. $CaCO_3$, 2. clay, 3. silt, 4. sand, 5. gravel. — ***Nannoplankton***: 1. Ericsonia muiri, 2. Sphenolithus radians, 3. S. pseudoradians, 4. S. moriformis, 5. S. sp., 6. Helicopontosphaera sp., 7. Cyclococcolithina sp., 8. Rhabdosphaera tenuis, 9. R. crebra, 10. Cyclocargolithus sp., 11. Coccolithus cf. marismontium. — ***Microfauna:*** 1. Valvulina terquemi, 2. Clavulina parisiensis, 3. Quincqueloculina sp., 4. Globulina gibba, 5. Asterigerina rotula, 6. Cibicides sp., 7. Pararotalia inermis. — ***Larger Foraminifera:*** 1. Nummulites burdigalensis, 2. N. partschi, 3. N. aff. partschi, 4. N. praelaevigatus, 5. N. aff. praelaevigatus, 6. N. aff. burdigalensis, 7. N. sp., 8. Alveolina sp., 9. Assilina placentula, 10. A. cf. placentula, 11. A. sp., 12. Orbitolites sp.

Kollányi with examining the microfauna, M. Monostori with studying the Ostracoda fauna, M. Jámbor-Kness with her results on the larger Forminifera and A. Kecskeméti-Körmendy on Mollusca.

The columnar sections of the key boreholes and the diagrams summarizing the analytical results are given in Fig. 68 to 72. The analytical results on the borehole Cn-850 are presented in detail by L. Gidai (1977) as well, so that in the case of this section we have restricted ourselves to publishing a summarizing profile and a section presenting the biostratigraphically most important fossils.

Darvastó Formation

Conglomerate member

On the Rendeki-hegy and also in the Kozma-tag subarea, at the base of the Eocene sequence, a 10- to 15-m-thick unit consisting mainly of gravel and conglomerate beds with interbedded silty clay layers can be found. Exposures of this peculiar, well-mappable formation occur in the so-called Haraszt subarea to the northeast of Sümeg and in quarries on the southwestern side of the Rendeki-hegy. Near the outcrops, the unit has been exposed in full thickness, between 89.4 and 100.4 m, by the borehole Cn-850 (Fig. 68).

Overlying the Upper Cretaceous Polány Formation, the basal part of the sequence is composed of conglomerate beds. The pebbles are constituted by grey, black and brown chert (radiolarite) and also by quartzite and siliceous schist. Most of the carbonate pebbles are lost to dissolution, just the cavities after dissolution being observable. The pebbles vary between 1 and 5 cm in size and their roundness varies, too. The matrix between the pebbles is generally calcite, less frequently marl or silty marl.

Fossils are very scant. All that has come into the fore is one *Clavagella* sp., a few *Foraminifera* specimens [*Asterigerina rotula* (Kaufmann), *Cibicides* sp.], further, single specimens of *Cycloplacolithella* sp. and *Discoaster* nannofosils.

The higher part of the member (89.4–93.6 m) is composed predominantly of silty clay and siltstone. The subunit ends at the top with gravelly sands. The pebbles are composed of chert, quartzite and limestone, 2 to 6 mm in diameter, very poorly rounded (0–1). The sands are composed for the most part of quartz grains, though quartzite and feldspar grains are rather frequent, too. The heavy mineral fraction accounts for 0.23%, from among the allothigenic minerals, magnetite is present in a rather considerable quantity.

From among the organic remains, tiny coalified plant fragments, the foraminiferal specimens quoted from the lower interval and also detritus of *Bryozoans*, *Echinoderms* and *Molluscs* could be observed.

The quarry-row on the slope of the Rendeki-hegy has exposed, in 4 to 8 m thickness, the lower beds of the conglomerate member overlying the Polány Formation. The most complete section of the conglomerate member is in the largest quarry of the quarry-row (Fig. 67, 1 and Plate XLIV, Fig. 2). In this quarry the Cretaceous formations are overlain by 1 to 3 m of yellow sand in which more and more pebbles occur as one proceeds upwards. Up in the section, this formation grades into conglomerates. The conglomerate beds have a total thickness of 6 m. The gravel lenses above them are contained in sands that may be correlated with the upper member mentioned in the borehole Cn-850.

The conglomerate member could be identified in the section of the borehole Crt-12, too (Fig. 69, 70), but the Eocene sequence there begins with 10 m of grey clay. From the bed containing tiny coalified vegetal debris, L. Rákosi recovered a "*Juglandaceae*" pollen assemblage.

The conglomerate member overlying the clay bed is 18 m thick. It is composed of gravel, conglomerate and sandstone beds between which thin layers of clay and siltstone are interbedded. The pebble grains are on the average smaller in size compared to those observed in the Haraszt exposures and in the borehole Cn-850 (below 1 cm). Sporadically, however, pebbles attaining even 10 cm in diameter can be found, too. Poorly rounded, the pebbles are made up of quartz, chert and dolomite.

In the upper part of the member (138.1–144.4 m) marine fossils can be found sporadically: *Nummulites praelaevigatus* Schaub, *Asterigerina rotulata* (Kaufmann), *Cibicides* sp. The pollen assemblage differs considerably from the basal clay layer.

As shown by L. Rákosi and K. Tóth (1980), the situation farther east, in the Csabrendek–Nagytárkány subarea, is similar—the conglomerats are underlain by 8 to 10 m of clay-marl (they proposed for it the name Cseteberek Argillaceous Marl).

In the southeastern foreland of the Rendeki-hegy the member is exposed by bauxite-exploratory boreholes within the Kozma-tag-subarea, where it forms the immediate overburden of the bauxite lenses (see the chapter Bauxite). On the eastern side of the Kozma-tag subarea the conglomerate member is covered by younger Eocene formations gradually decreasing in thickness eastwards owing to erosion. The Eocene overburden in the eastern part of the area is completely lacking already: here the member is overlain by Oligo-Miocene and Neogene gravels. To separate the gravel formations of different age from one another in this area requires a detailed analysis of the pebbles.

In the southern part of the Kozma-tag subarea the thickness of the Darvastó Formation decreases, the conglomerate member missing from the sequence; the boreholes Ck-181 and Cn-211 exposed only a few metres of sandy, gravelly marl beneath the Szőc Limestone. In the borehole Ck-177, in turn, bauxite and then carbonaceous clay are superimposed on the Senonian limestone surface.

In K. Tóth's opinion (oral communication, 1977), an intertonguing of the conglomerate and the argillaceous marl or the pinching-out of the conglomerate member can be observed in the adjacent Csabrendek–Nagytárkány bauxite area.

At the top of the Hárshegy the conglomerate member is greatly reduced in thickness (8 m in the borehole S-30), while in the section exposed in the Gerinc quarry it is completely missing. Here the Upper Cretaceous limestone and/or the bauxites filling its fissures are overlain, with a thin argillaceous, basal bed, directly by the Szőc Limestone.

On the edge of the Városi-erdő, in the borehole Bd-17, the coarse-detrital sediments are also lacking in the exposed section.

Upper member of the Darvastó Formation

Above the conglomerate member or, in this absence, directly above pre-Eocene formations, there occur grey to yellowish-grey, pelitic beds that are very similar to the lower beds exposed in the section of the Darvastó VI mine pit.

In the borehole Cn-850 (80.5–90.0 m) this unit is readily dissociated from the underlying conglomerate member and the overlying limestone with larger Foraminifera. The lithology is diversified — grey (secondarily, yellowish-brown) siltstones, argillaceous marls, marls and calcareous marls alternate with argillaceous limestones. The sand content of the rocks varies between 5 and 40%. As shown by mineralogical analyses, 60 to 70% of the sand grains is quartz, 7 to 13% is quartzite, 10 to 13% is plagioclase and 3 to 8% is glauconite. The amount of the heavy fraction is 0.2 to 1.3 per cent by weight. From among the allothigenic grains it is magnetite, ilmenite, garnet, tourmaline and chlorite that are present in significant quantities.

The fossils at the lower boundary show a sudden increase in quantity. The *larger Foraminifera* are represented by a large number of individuals and by several genera. The individual species and their quantities are shown in Fig. 71.

In addition to *Nummulites laevigatus* LAMARCK, an index fossil of great stratigraphic value, *Nummulites perforatus* MONTFORT appears already in the lower part of the unit, becoming gradually more frequent higher up the profile.

In addition to these, the following Nummulites species are encounterable:

Nummulites partschi DE LA HARPE, A
Nummulites aff. *pernotus* SCHAUB., A
Nummulites globulus LEYMERIE, A
Nummulites anomalus DE LA HARPE, A
Nummulites burdigalensis DE LA HARPE

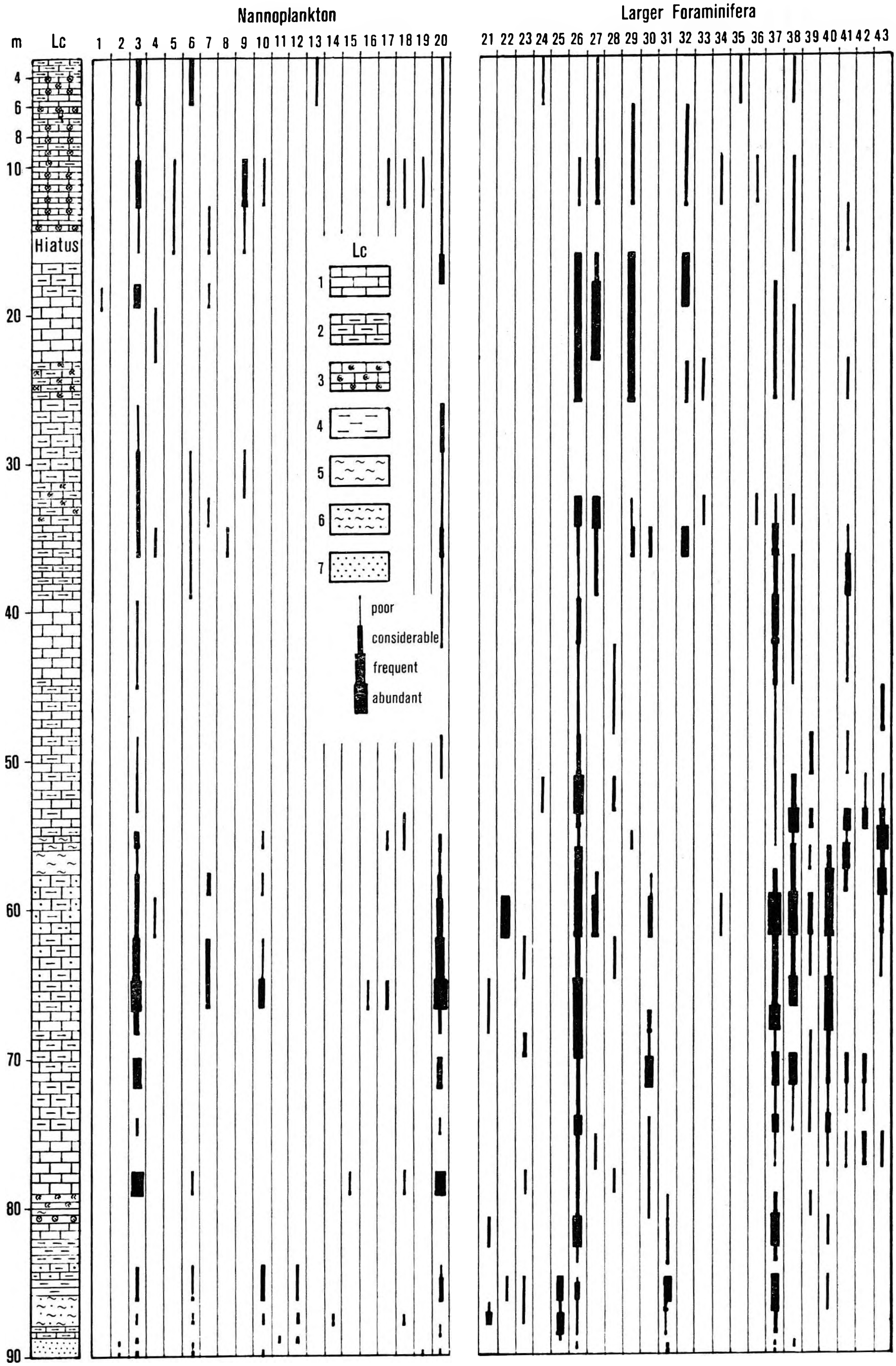
It is noteworthy that, in M. JÁMBOR-KNESS' option based on the study of the fossils, these species are not allochtonous.

Assilina exponens (SOW.), Form A, appears at the base of the sequence being encounterable in fair abundance throughout the unit. Let us add to this, that at the base of the unit, M. JÁMBOR-KNESS found one specimen of *Assilina spira* DE ROISSY, Form A too, which is the zonal index fossil of the next larger Foraminifera zone.

→

Fig. 71. Nannoplanktonic and larger foraminiferal record of the borehole Csabrendek Cn-850

Lithologic column (Lc): 1. limestone, 2. argillaceous limestone, 3. limestone with larger Foraminifera and lumachelle, 4. clay, 5. marl, 6. sandy marl, 7. sand. — *Nannoplankton:* 1. Discolithina rimosa, 2. Cyclococcolithus gammation, 3. Coccolithus pelagicus, 4. C. eopelagicus, 5. Reticulofenestra placomorpha, 6. Braarudosphaera bigelowi, 7. B. discula, 8. Micrantholithus crenulatus, 9. Pemma rotundum, 10. Discoaster barbediensis, 11. D. mirus, 12. D. lodoensis, 13. D. trinus, 14. D. aff. diastypus, 15. D. cf. crassus, 16. Clathrolithus spinosus, 17. Chiasmolithus grandis, 18. Ch. solitus, 19. Neococcolithes dubius, 20. Cycloplacolithella formosa. — *Larger Foraminifera:* 21. Nummulites partschi A, 22. N. pernotus A, 23. N. globulus A, 24. N. anomalus A, 25. N. burdigalensis A, 26. N. perforatus A, 27. N. variolarius A, 28. N. aturicus B, 29. Nummulites millecaput A, B, 30. N. sismondai B. 31. N. laevigatus A, 32. N. incrassatus A, 33. N. baconicus B, 34. Discocyclina nummulitica, 35. D. papyracea, 36. D. scalaris, 37. Assilina exponens A, 38. A. spira A, 39. A. praespira A, 40. A. pustulosa A, 41. Alveolina aff. callosa, 42. Alv. munieri, 43. Alv. aff. tenuis


Nannoplankton
Larger Foraminifera
m
Lc
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43
4
6
8
10
20
30
40
50
60
70
80
90
Hiatus
Lc
1
2
3
4
5
6
7
poor
considerable
frequent
abundant

From the 84.0 to 84.7 m interval of the member, A. KEREKES determined a fairly rich autochtonous nannoplanktonic association. Most frequent forms of this association are:

Coccolithus pelagicus (WALLICH)
Cycloplacolithella formosa (KAMPT.)
Discoaster lodoensis BRAML. et RIED.
Discoaster aff. *lodoensis* BRAML. et RIED.
Discoaster barbadiensis TAN
Discoaster aff. *diastypus* (BRAML. et SULL.)

Mollusca are present in a rather poor number of species and individuals. Forms identified:

Ampullina cfr. *perusta* DEFR.
Cardium sp.
Spondylus sp.
Lima sp.
? *Natica* sp.

Some forms, like the representatives of *Ostrea* and *Clavagella*, are suggestive of a marine environment.

In the lower half of the unit, 84.0 to 90.0 m, L. RÁKOSI identified an ancient Juglandaceae vegetation that can be traced even regionally in Transdanubia.

In the borehole Crt-12 (Fig. 70), above the conglomerate member and below the Szőc Limestone abounding with larger Foraminifera, a grey silty marl subunit could be distinguished (117.0–138.1 m). The basal part of this (below 136.3 m) is poor in organic remains, but eventually the amount of *Foraminifera* and *Mollusca* will suddenly increase. Between 135.0 and 136.3 m, A. KECSKEMÉTI-KÖRMENDY found one specimen of brackish-water *Brachyodontes corrugatus* (BRONGN.) in addition to marine forms. From the beds above 136.3 m, M. JÁMBOR-KNESS determined the following larger Foraminifera: *Nummulites praelaevigatus* SCHAUB., *N. partschi* DE LA HARPE, *N. burdigalensis* DE LA HARPE, *Assilina placentula* DESH., *Alveolina* sp. Among the other Foraminifera solely benthonic forms can be found in a low number of species and specimens. As shown by M. BÁLDI-BEKE, the nannoplanktonic assemblage abounds in forms redeposited from the Cretaceous (*Watznaueria bernesae*).

Outcrops of the upper member of the Darvastó Formation are unknown from the study area, but drilling results have proved its being common.

Bio- and chronostratigraphy

It is the larger Foraminifera and the nannoplanktonic assemblages that are of most important time marker value.

The larger Foraminifera appear above the conglomerate member, being represented, in the borehole Crt-12, by an assemblage composed of *Nummulites praelaevigatus*, *N. partschi*, *N. burdigalensis*, and *Assilina placentula* which M. JÁMBOR-KNESS assigned to the Upper Cuisian. According to the international stratigraphic practice, the representatives of *N. laevigatus* indicative of the very base of the Lutetian stage (CH. POMEROL 1973) appear in calcareous marl and limestone beds assignable, upon lithological features, to the Szőc Formation. In the borehole Cn-850, *N. laevigatus* appears already in the marls overlying the gravels.

The nannoplankton occurs together with the larger Foraminifera. As observed by M. BÁLDI-BEKE, in the borehole Crt-12, *Rhabdosphaera inflata* BRAML. et SULL. and *Discoaster sublodoensis* BRAML. et SULL. occuring in the upper member of the formation are suggestive of a deeper part of the Middle Eocene. The presence of *Sphenolithus pseudoradians* BRAML. et WILC. precludes, in turn, a pre-Middle Eocene age of the member (the first appearance of the species is at 132 m).

From the beds overlying the conglomerate member in the borehole Cn-850, A. KEREKES identified *Discoaster lodoensis* BRAML. et RIED.—a zonal index fossil of the middle to upper part of the Cuisian.

According to palynological results (L. RÁKOSI), the clays underlying the conglomerate beds in the borehole Crt-12 contain a spore-pollen assemblage indicative of an ancient Juglandaceae vegetation (*Plicapollis pseudoexcelsus–Triporopollenites urkutensis* Assemblage Zone) which is in favour of an assignment to the Lower Eocene. In the borehole Cn-850 a similar spore-pollen assemblage could be observed above the conglomerate member. In the borehole Crt-12, however, a different type of vegetation, probably that of the Middle Eocene already, could be detected above the conglomerates.

Thus the chronostratigraphic evaluation has to be based on the biostratigraphic evidence remarkably pregnant with contradictions.

The beds of marine fossils overlying the conglomerate member may represent the base of the Lutetian (*N. laevigatus*—borehole Cn-850), but in some places the deposition of pelitic sediments seems to have begun as early as the Cuisian. The conglomerate member as well as the clays and argillaceous marls underneath appear to be assignable to the Cuisian. The upper, marly, member, however, certainly belongs to the lower part of the Lutetian.

Paleoenvironment

At the base of the Darvastó Formation near Sümeg generally coarse-detrital formations occur. The clays of grey colour with coalified plant remains observed below the conglomerate member in the borehole Crt-12 seem to be of lacustrine, paludal origin. Lacking any marine or brackish-water fossils, they contain spores and pollen grains of terrestrial plants. The presence of plenty of allochtonous Upper Cretaceous pollen grains indicates an erosion of Senonian formations.

In evaluating the genetic circumstances of the conglomerate member we can rely on sporadical paleontological data and the results of analyses of the gravels. The fossils recovered *(Mollusca, Foraminifera, Bryozoa, Echinodermata, nannoplankton)* suggest that the detrital sediment was deposited in a seawater of normal salinity. The low quantity of fossils may be due to forbidding conditions for life and disadvantageous fossilization conditions.

In the material of the pebbles, the lithology of the directly underlying Senonian can seldom be recognized, if at all. This fact and the feeble roundness of the noncarbonate pebbles suggest the presence of a sediment other than abrasion product. The pebbles—for the most part of Mesozoic origin—indicate, with a view to their lithologic composition, a rather short distance of transport. This fact is supported by the observation that the roundness of the carbonate pebbles attains even the 3rd grade, while the siliceous pebbles are generally of 1st grade. Consequently, it is probable that we have to do with an alluvium introduced by streams into the sea, but left unaffected by the surfs. The finer-grained detritus too may have been brought into the sedimentary basin by fluviatile transport. At any rate, this model of deposition will account also for the protection the bauxite deposits had against abrasion. Namely, in case of abrasional activities, the preservation of earlier-deposited bauxite bodies would be less plausible.

In the borehole Cn-850, at the boundary between the lower and upper members, the fauna showing a decrease in salinity and the absence of nannoplankton is indicative of partial landlocking. The presence of pollen grains of *Nipa (Echimorphomonocolpites echinatus)* suggests that a mangrove vegetation had evolved. The introduction of pebble-size grains discontinued and fine terrigeneous detritus was brought in that derived, probably in a considerable part, from the erosion of a Barremian-Aptian sequence (redeposited nannoplankton and spores and pollen grains). The deposition took place in a near-shore, shallow water environment, where organic-rich muds were deposited.

Szőc Limestone Formation

The Szőc Formation is a biogenic limestone body which contains the shells of larger Foraminifera, usually in rockforming quantities. Essentially, this is the unit which was referred to as "Hauptnummulitenkalk" (Main Nummulites Limestone) in the earlier literature. On the basis of the abounding fossils, strikingly different even when viewed with an unaided eye, E. Dudich (1978) proposed to divide the formation into the following (informal) members: 1. *Nummulites laevigatus* Member, 2. *Assilina spira* Member, 3. *Nummulites perforatus* Member, 4. *Nummulites millecaput* Member. This classification follows essentially the earlier (G. Kopek, T. Kecskeméti, E. Dudich 1966) so-called horizon scale. In the study area this classification cannot be used without modification either in the litho- or the biostratigraphical sense. A part or the whole of the unit characterized by the predominance of *Nummulites laevigatus* is represented by grey marls and calcareous marls, thus being part of the Darvastó Formation. It is overlain by a limestone unit that can be assigned to the Szőc Formation. On the basis of rock composition and textural and structural characteristics and in terms of the rockforming fossils two distinct units of member rank can be singled out. The lower unit is composed of thick-bedded Assilina-Alveolina limestones, the upper one being characterized by thin-bedded, often glauconitic and argillaceous limestones with *Nummulites millecaput.*

The borehole Cn-850 intersected the formation in a thickness of almost 80 m (2.7–79.0 m) (Fig. 68, 71). The rock is light brownish-grey to grey limestone or argillaceous limestone. Its clay content in the lower part of the formation (55.8–80.5 m) varies between 5 and 20%, in the middle part it is only about 5%, but it is more in the upper part (2.7–19.5 m), where the rock is composed of an argillaceous limestone.

The larger Foraminifera, as a rule, are abundant, forming 80 to 90% of the rock in some beds. However, beds free from larger Foraminifera can be observed, too. The intervals showing an enrichment or an impoverishment of the fauna are of local character, not being traceable over larger distances.

In terms of larger Foraminifera, as already mentioned, two subunits could be distinguished (Fig. 71).

1. The lower subunit (36.1–79.0 m) is characterized by the predominance of species of the genera *Alveolina* and *Assilina* [*Assilina spira* de Roissy, *A. praespira* Douv., *A. exponens* (Sow.), *A. pustulosa* Donc., *Alveolina elongata* d'Orb., *A. fragilis* Hott., *A. fusiformis* Sow.]. In addition, *Nummulites peforatus* Montfort can be encountered in a great quantity too.

2. In the upper subunit (5.7–36.1 m) *Nummulites millecaput* BOUBÉE predominates, but in the deeper parts (below 17 m) *N. perforatus* MONTFORT and *N. variolarius* (LAMARCK) are very frequent, too.

Beside larger Foraminifera, the presence of smaller Foraminifera, Ostracoda and Mollusca is also common in the faunal assemblage (Fig. 68). In the beds poor in larger Foraminifera (25.4–31.6 m) the remains of *Lithothamnium*, *Brachiopoda*, *Mollusca* and *smaller Foraminifera* could be observed. The nannoplanktonic assemblage is shown in Fig. 71.

In the borehole Crt-12, the basal, lithologically transitional part of the formation (113–117 m)

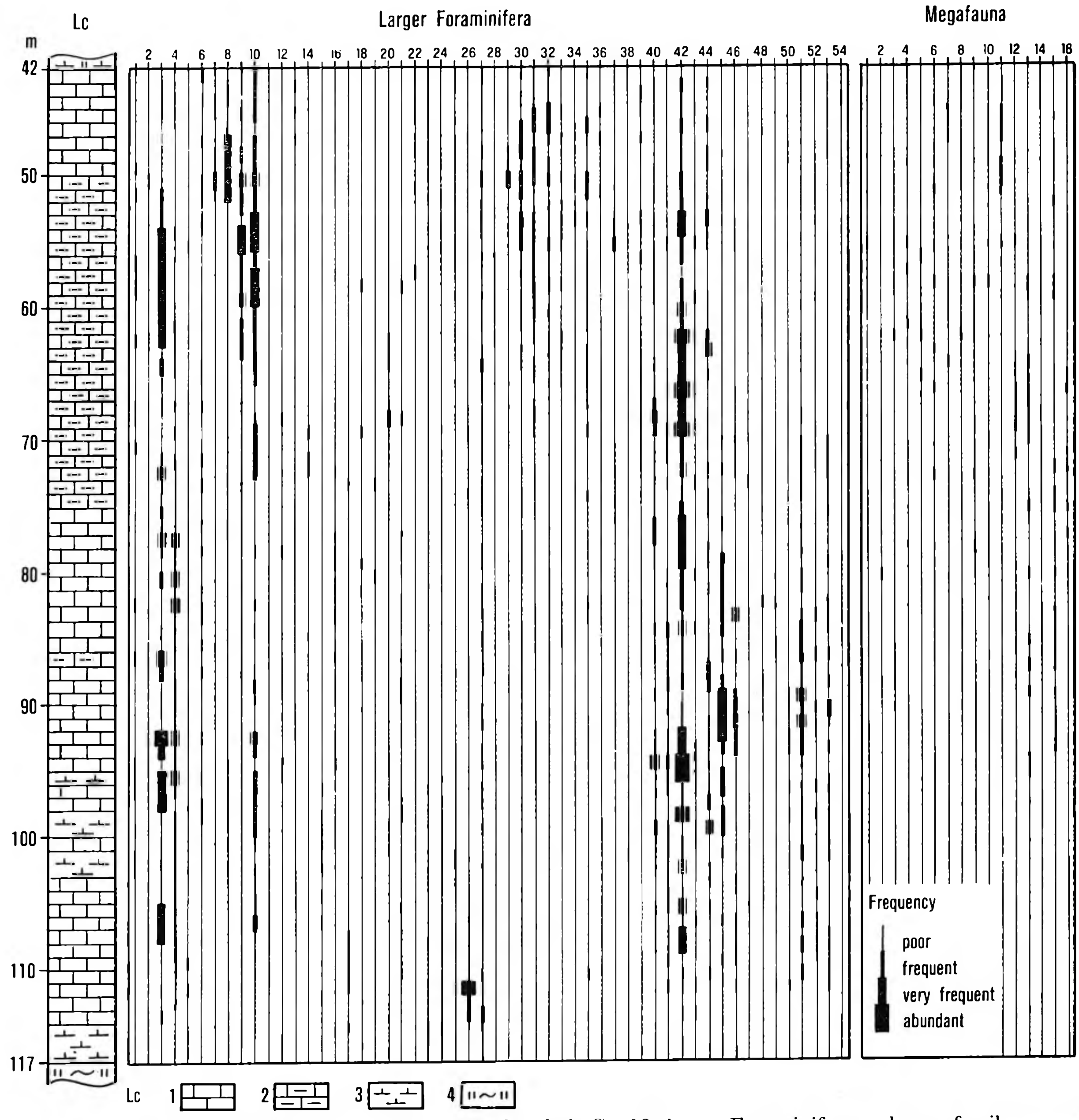


Fig. 72. The Szőc Formation interval of the borehole Crt-12: larger Foraminifera and megafossils

Lithologic column (Lc): 1. limestone, 2. argillaceous limestone, 3. calcareous marl, 4. silty marl. — *Larger Foraminifera:* 1. Nummulites apertus, 2. N. brongniarti, 3. N. perforatus, 4. N. ex gr. perforatus, 5. N. deshayesi, 6. N. striatus, 7. N. anomalus, 8. N. incrassatus, 9. N. millecaput, 10. N. variolarius, 11. N. aff. striatus, 12. N. aff. partschi, 13. N. aff. discorbinus, 14. N. dufrenoyi, 15. N. sismondai, 16. N. aff. sismondai, 17. N. aff. globulus, 18. N. aff. urbiensis, 19. N. aff. puschi, 20. N. aff. dufrenoyi, 21. N. bakonicus, 22. N. aff. millecaput, 23. N. praelaevigatus, 24. N. aff. burdigalensis, 25. N. gidaiensis nov. sp., 26. N. laevigatus, 27. N. sp., 28. Discocyclina scalaris, 29. D. aspera, 30. D. nummulitica, 31. D. papyracea, 32. D. pratti, 33. D. sella, 34. D. varians, 35. D. sp., 36. Operculina alpina, 37. O. parva, 38. O. granulosa, 39. O. sp., 40. Assilina spira, 41. A. praespira, 42. A. exponens, 43. A. pustulosa, 44. A. sp., 45. Alveolina elongata, 46. A. fragilis, 47. A. aff. elongata, 48. A. aff. fragilis, 49. A. fusiformis, 50. A. gigantea, 51. A. sp., 52. Orbitolites complanatus, 53. O. sp., 54. Actinocyclina sp. — *Megafossils:* 1. Tubulostium spirulaeum, 2. T. sp. 3. Chlamys multicarinata, 4. C. biarritzensis, 5. C. aff. biarritzensis, 6. C. sp., 7. Pecten sp., 8. Anomia tenuistriata, 9. A. sp., 10. Ostrea cf. plicata, 11. O. sp., 12. Rotalia sp., 13. Asterigerina rotula, 14. Cibicides sublobatulus, 15. C. sp., 16. Sphaerogypsina sp.

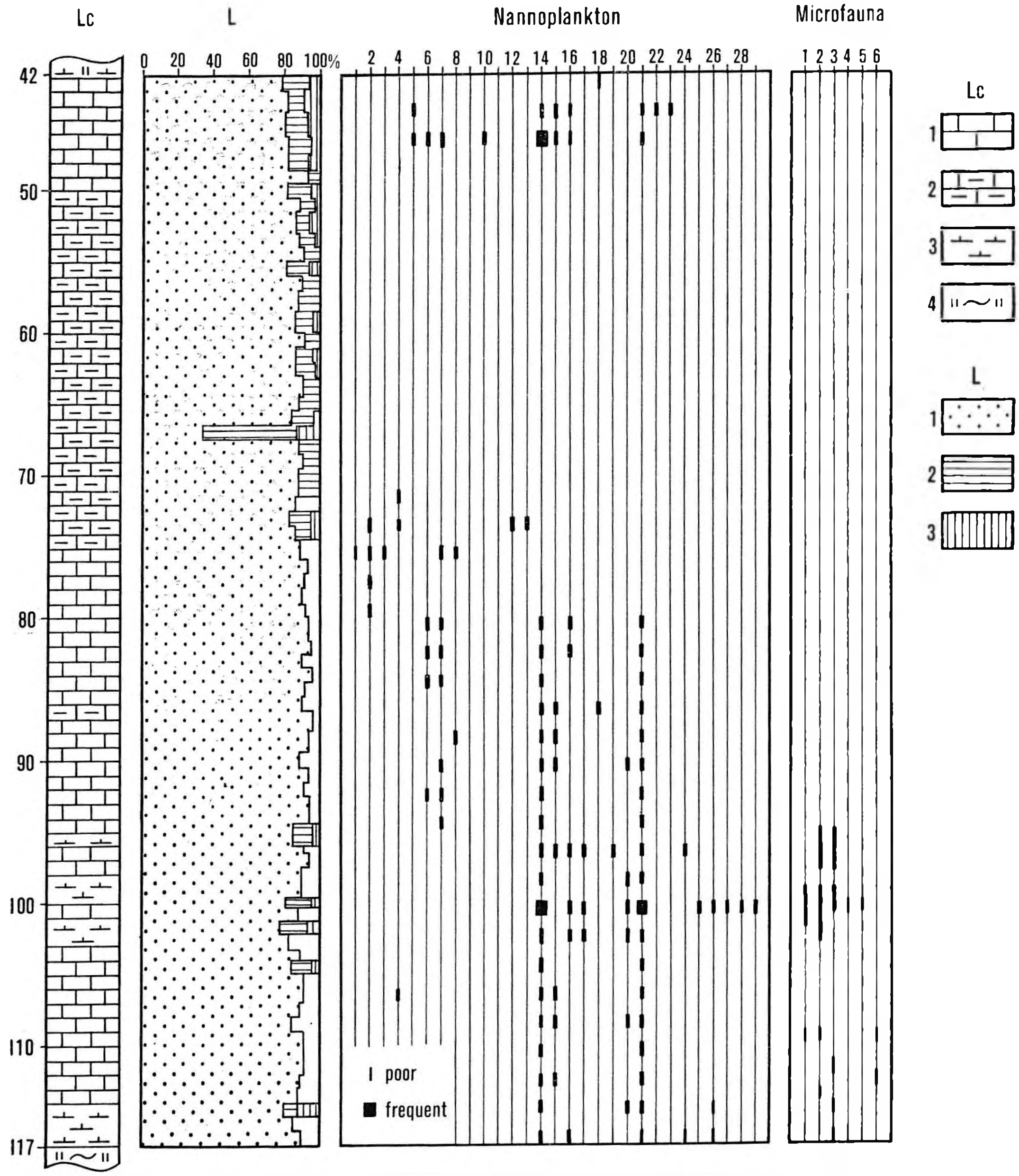
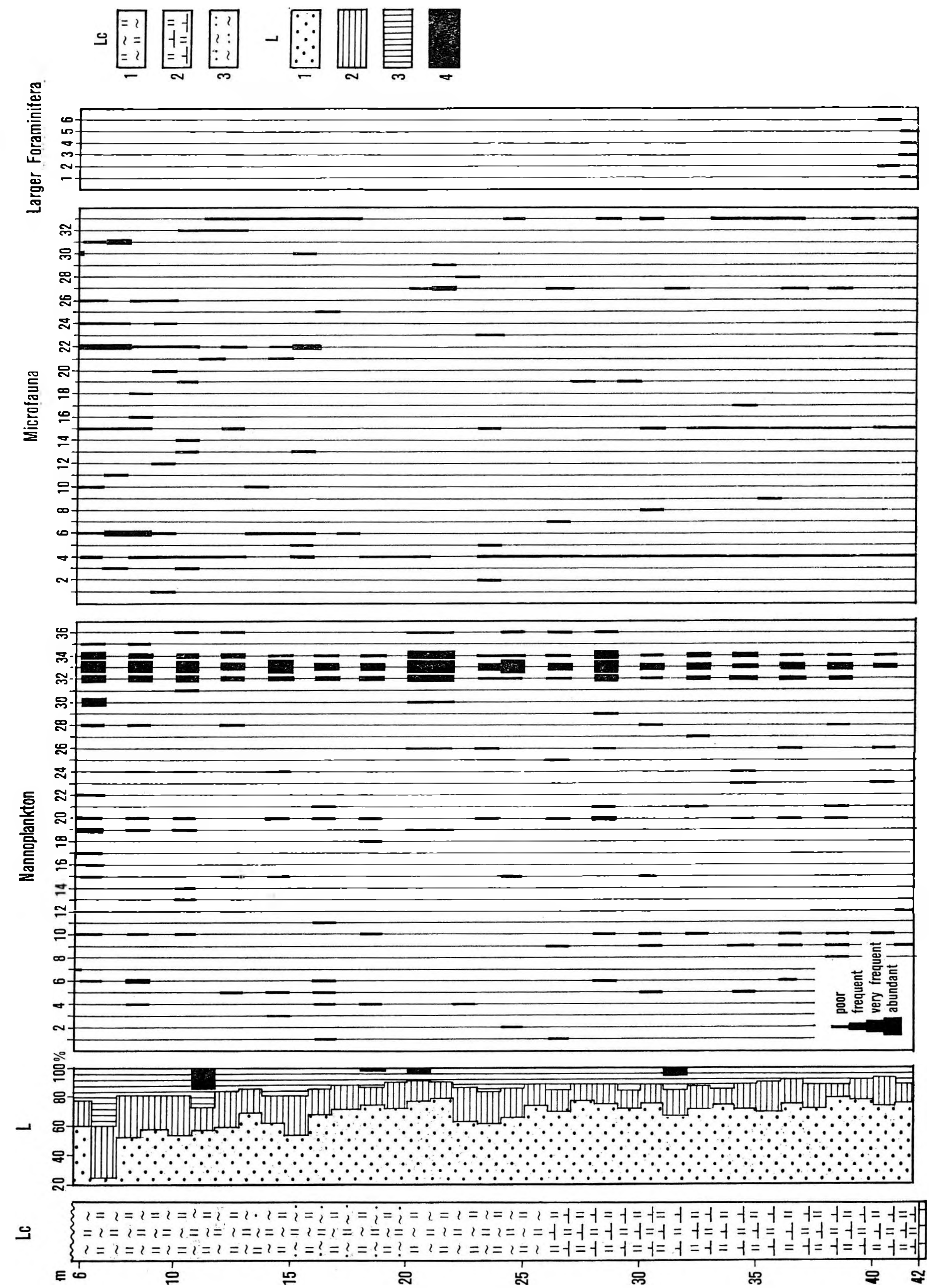


Fig. 73. The Szőc Formation interval of the borehole Crt-12: lithologic column and analytical record

Lithologic column (Lc): 1. limestone, 2. argillaceous limestone, 3. calcareous marl, 4. silty marl. — ***Lithologic composition*** (L): 1. $CaCO_3$, 2. clay, 3. silt. — ***Nannoplankton:*** 1. Discolithina pulchra, 2. D. sp., 3. Coccolithus eopelagicus, 4. Reticulofenestra bisecta, 5. R. cf. bisecta, 6. R. sp., 7. Braarudofenestra bigelowi, 8. B. sp. indet., 9. Pemma rotundum, 10. Discoaster barbadiensis, 11. D. crassus, 12. D. sublodoensis, 13. D. cf. lodoensis, 14. Cyclocargolithus sp., 15. Cyclococcolithina formosa, 16. Sphenolithus moriformis, 17. S. radians, 18. S. cf. radians, 19. S. cf. furcotolithoides, 20. S. sp., 21. Ericsonia muiri, 22. Chiasmolithus grandis, 23. C. solitus, 24. Sphenolithus pseudoradians, 25. Helicopontosphaera sp., 26. Cyclococcolithina sp., 27. Rhabdosphaera tenuis, 28. R. inflata, 29. Coronocyclus nitescens. — ***Microfossils:*** 1. Quinqueloculina sp., 2. Asterigerina rotula, 3. Cibicides sp., 4. Planulina sp., 5. Sphaerogypsina sp., 6. Triloculina angularis

is dominated by *N. laevigatus*, though *N. perforatus* appears, too (Fig. 72). The topmost part of the formation in the borehole Cn-850 is absent, but this subunit too is well exposed in the borehole Crt-12 (Fig. 72 and 73, Plate XLVI).

A gradual transition in the sequence is observable between the Szőc and Csabrendek Formation. The features of the Szőc Limestone disappear gradually to be replaced progressively by the characteristics of the Csabrendek Marl. As one proceeds upwards, the carbonate content decreases (from 90% to 75% $CaCO_3$), the clay content increases, the argillaceous limestone is replaced by calcareous marl, the colour turns greenish-grey to grey. Near the formation boundary (from 52 m on) the glauconite content shows a marked growth, reaching 80 to 85% of the light mineral fraction. (The frequent occurrence of glauconite grains is characteristic of the lower part of the Csabrendek Marl, too.) The glauconite often fills the chamberlets of Foraminifera.



Lc
L
Larger Foraminifera
Microfauna
Nannoplankton
poor
frequent
very frequent
abundant
m

The amount of the specimens of larger Foraminifera, especially of those of *Nummulites millecaput* characteristic of the upper part of the formation, is reduced (Fig. 72). The fossils abounding in the Csabrendek Marl appear (e.g. *Tubulostium spirulaeum* in the 47.5 to 48.5 m interval). The upper boundary of the formation can be drawn there, where the larger Foraminifera cease to play a rockforming role. This coincides with the disappearance of *N. millecaput* (42.0 m).

The surface extension of the formation is shown in Fig. 67. There are outcrops in the valleys of slopes around the Rendek-hegy and near the hilltop level (e.g. "Fehér kövek" = White Stones), in the ravines lacing the hill and also in Csabrendek village. In the vicinity of Csabrendek, several minor quarries have exposed the higher parts of the formation (Plate XLIV, Fig. 1).

The boreholes drilled for construction raw materials and bauxites on the Rendek-hegy and the Kozma-tag subarea cut the formation in a number of cases, finding it, as a rule, in a facies similar to the type section of the borehole Cn-850. In some cases (e.g. the location of the borehole M 1/F in Fig. 67), however, a lithofacies of calcarenite and calcilutite texture, poor in larger Foraminifera, but abounding with red algal remains, could be observed.

To the east of the Rendek-hegy a number of boreholes other than Crt-12 (Cn-562, -563 and -593) exposed the Szőc Limestone as underlying the Csabrendek Marl.

On the hilltop of the Hárs-hegy the lower, Alveolina-Assilina-bearing limestone beds of the formation overlie Darvastó Formation of reduced thickness (boreholes S-30 and Süt-8). In the upper yard of the Gerinc quarry the limestone overlies, with a marly layer of reduced thickness in-between, directly the Upper Cretaceous limestone or the bauxite filling the funnel-shaped dolinas in it.

Bio- and chronostratigraphy

The primary basis of chronocorrelation is the assemblage of larger Foraminifera (Fig. 71 and 72). In the discussion of the formations we have already mentioned that *Nummulites laevigatus* disappears by and large at the boundary of the Darvastó and Szőc Formations, thus the biozonal boundary and the formation boundary roughly coincide in this area.

As shown by M. Jámbor-Kness, in terms of foraminiferal assemblages and the abundances of the fossils, two biozones could be distinguished within the Szőc Formation: 1. the *Assilina spira* Zone and 2. the *Nummulites millecaput* Zone. No separate *N. perforatus* unit (horizon) is distinguishable. As shown by a detailed study of the larger Foraminifera (boreholes Cn-850, Crt-12), the individuals of *Assilina spira* are encounterable in considerable quantities up to the appearance of *N. millecaput. N. perforatus*, however, appears already with *N. laevigatus*, being observable associated with specimens of *Assilina spira* and *N. millecaput* as well, mainly as dominant or subdominant species.

Since the appearance of *N. laevigatus* indicates the base of the Lutetian and since the Csabrendek Formation represents the top of the Middle Eocene (with nannoplankton and a smaller foraminiferal assemblage in the borehole Crt-12) or possibly the very base of the Upper Eocene (larger foraminiferal fauna), the Szőc Formation as a whole can be assigned to the Lutetian stage.

Paleoenvironment

Composed of biogenic carbonate rocks, the formation was deposited in a shallow warm-water sea of normal salinity. The paleoenvironment is interpreted, similarly to the case of the Upper Cretaceous rudist-bearing limestone, as a shallow-water carbonate platform, the only difference consisting in that the role of the main lime-secreting fossil group has been taken over—from the extinct rudists—by *larger Foraminifera* now having their flourish. As a matter of course, there may be marked differences in the development of minor paleoenvironmental units within the platform, discrepancies that may be ascribed primarily to differences in the ecological features of the predominant fossil group. Foraminiferal shells were obviously insufficient for the construction of biogenic structures

←

Fig. 74. The Csabrendek Marl Formation interval of the borehole Crt-12: lithologic log and analytical record

Lithologic column (Lc): 1. silty marl, 2. silty calcareous marl, 3. sandy marl. — *Lithologic composition* (L): 1. $CaCO_3$, 2. clay, 3. silt, 4. sand. — *Nannoplankton:* 1. Discolithina pulchra, 2. D. multipora, 3. Rhabdolithus sp., 4. Zygrhabdolithus bijugatus, 5. Coccolithus eopelagicus, 6. Reticulofenestra placomorpha, 7. R. bisecta, 8. R. cf. bisecta, 9. R. sp., 10. Braarudosphaera bigelowi, 11. B. sp., 12. Pemma rotundum, 13. P. cf. rotundum, 14. P. sp., 15. Discoaster barbadiensis, 16. D. saipanensis, 17. D. floreus, 18. D. sp. ind., 19. D. sp., 20. Sphenolithus moriformis, 21. S. radians, 22. S. cf. radians, 23. S. pseudoradians, 24. S. furcatolithoides, 25. S. cf. furcatolithoides, 26. S. spiniger, 27. S. sp., 28. Chrasmolithus grandis, 29. C. cf. grandis, 30. C. solitus, 31. Lanternithus minutus, 32. Ericsonia muiri, 33. C. sp., 34. Cyclococcolithina formosa, 35. C. protoannula, 36. Helicopontosphaera sp. — *Microfossils:* 1. Globorotalia broedermanni, 2. G. sp., 3. Planulina costata, 4. Cibicides sp., 5. Globigerapsis kugleri, 6. G. index, 7. G. sp., 8. Pararotalia inermis, 9. Dorothia sp., 10. Truncorotaloides rohri, 11. Tritaxia szabói, 12. Tursenkoina hungarica, 13. Hantkenina dumblei, 14. H. longispira, 15. Spiroplectammina carinata, 16. Textularia sp., 17. Valvulina sp., 18. Quinqueloculina sp., 19. Lenticulina sp., 20. Marginulina gladius, 21. M. fragaria, 22. Dentalia elegans, 23. D. sp., 24. Bolivina elongata, 25 Uvigerina multistriata, 26. U. sp., 27. Asterigerina rotula, 28. Rotalia sp., 29. Halkyardia minima, 30. Globigerina yeguaensis, 31. G. corpuleta, 32. G. linaperta, 33. G. sp. — *Larger Foraminifera:* 1. Nummulites anomalus, 2. N. millecaput, 3. N. variolarius, 4. N. sp., 5. Discocyclina pratti, 6. Operculina alpina (reefs) that should have led to remarkable sedimentary differentiation of the platform. For this rea son, the resulting facies pattern is less varied than it is the case e.g. with the Ugod Limestone.

Anyway, two lithofacies types are readily distinguishable: 1. a rock made up mainly of larger foraminiferal shells and 2. an aphaneritic, finely crystalline limestone with but sporadical larger Foraminifera in which nodules of *red algue*, skeletal elements of *echinoderms* and, in certain cases, even *crab* remains are usually quite frequent.

During the formation of larger foraminiferal "lumachelles" the shells of organisms lived in the vicinity of the site of accumulation were deposited. Thus this rock type was formed in areas most favourable from the viewpoint of biogenic carbonate segregation, i.e. in the agitated parts of the platform well-penetrated by sunlight and rich in oxygen and nutrients; while the fine-grained, calcareous mud to bioclastic sediments were deposited in the relatively deeper parts of the platform, where the water was less agitated. Since a sharp morphological or other ecological boundary cannot be supposed to have existed between the two paleoenvironments, the situation of the environments may have changed considerably even within a short span of time and therefore the relationship of the facies, their intertonguing, seems to be very complex.

The fact that glauconite tends to become abundant in the upper part of the formation seems to be due to the volcanism that set in that time in the Lake Balaton–Velence Mountains line, even though the glauconite does not derive directly from a halmyrolitic alteration of the tuff material of the volcanism. The formation of glauconite may often be linked with the decay of organic matter, thus being associated with the microenvironment of foraminiferal shells, etc.

Csabrendek Marl Formation

The term Csabrendek Marl Formation was proposed—in agreement with the *Eocene Subcommission of the Stratigraphic Commission of Hungary*—by E. Dudich (1977). Accordingly, the Csabrendek Formation would correspond to that unit referred to in the earlier literature as "glauconitic-tuffaceous marl" or "marls with crabs and *Tubulostium*", respectively. The proposal, however, does not include either the designation of a stratotype or a description. In our opinion, the borehole Crt-12 put down at a distance of 2 km southeast of Csabrendek and analyzed in detail provides a good representation for the formation and therefore we recommend it for stratotype. The complete core material of the borehole is deposited in the Szépvízér Core Depository of the Hungarian Geological Institute.

Stratotype section: borehole Crt-12

Beneath a thin soil and Pannonian layer, the borehole exposed the Csabrendek Formation in the interval between 5.7 and 42.0 m. The upper part of the unit is constituted by silty argillaceous marls. The $CaCO_3$ content increases progressively from 25% at the top to 75% at the bottom and the clay and silt content decreases parallel to this (Fig. 74) so that the calcareous marl lithofacies type is characteristic in the lower interval. The rock colour is grey to light grey throughout the unit or, at the base, owing to the glauconite content, it turns greenish-grey.

Typical of the unit in question, glauconite between 7.5 and 9.0 m appears in larger aggregates, nodules, then, below 17 m depth, it is represented by smaller grains. The maximum of its abundance was observed in the 19.0 to 20.0 m interval. According to micromineralogical results (E. Sárközi-Farkas), the glauconite in the 17 to 42 m interval accounts for 75 to 95% of the light mineral fraction. Between 25 and 29 m even biotite grains could be identified. From among the allothigenic heavy minerals, garnet and tourmaline could be observed in almost all samples: in the light fraction quartz, quartzite and plagioclase are common.

The megafossils, primarily larger Foraminifera, show a marked decrease in quantity compared to the Szőc Formation. Larger quantities of larger Foraminifera are observable only in the lowermost, transitional beds (38–42 m) (Fig. 72) [*Nummulites anomalus* de la Harpe, *N. variolarius* (Lam.), *Discocyclina papyracea* (Boub.), *D. pratti* (Mich.), *Actinocyclina* sp., *Operculina alpina* Douv.]. Higher upwards single larger foraminiferal specimens can be found but sporadically.

Planktonic Foraminifera are frequent in the topmost part of the formation (15.7 to 16.0 m) (species of the genera *Globigerina*, *Globigerapsis*, *Globorotalia*, *Truncorotaloides*). Farther downwards the plankton gets gradually impoverished; only one or two specimens per sample are observable and even the benthonic assemblage is meagre and poorly preserved (Plate XLVII, Fig. 73).

Molluscs occur sporadically. Characteristic species: *Tubulostium spirulaeum* (Lam.), *Variamussium squamulus* Korobkov, *V. fallax* (Korobkov). Other megafossils: *crab's nippers*, *Brachiopoda*, *Bryozoa*, *Echinoidea*, *fish scales* and *fish teeth*.

The nannoplanktonic assemblage in the upper part of the formation (5.7–30 m) is extremely rich in species and individuals, becoming substantially poorer underneath (30–40 m) (Fig. 74). The spore-pollen assemblage is poor in both species and individuals throughout the sequence.

In addition to borehole Crt-12, the formation was penetrated in a considerable thickness by the boreholes Cn-563 and Cn-1055. Over quite a small area, at the bottom of the Pannonian gravel pit by the road from Csabrendek to Kozma-tag, the basal beds of the formation do even crop out.

Bio- and chronostratigraphy

The chronostratigraphic assignation of the formation cannot be considered finally settled. G. Kopek, T. Kecskeméti and E. Dudich (1966) placed the unit, on the basis of the larger Foraminifera, at the top of the Middle Eocene and they did not change their opinion even later. On the basis of larger Foraminifera from the borehole Crt-12, however, M. Jámbor-Kness places the unit as a whole at the base of the Upper Eocene.

In the light of planktonic Foraminifera [*Truncorotaloides rohri* (Brönn. et Berm.), *Globorotalia broedermanni* Cush. et B., *Globigerapsis kugleri* Bolli, Loeb. et Tapp.), K. Kollányi believes that the unit in question belongs to the Globorotalia lehneri Zone of the Lutetian.

Based on her studies of the nannoplankton, M. Báldi-Beke's opinion is that even the topmost beds from the borehole Crt-12 are assignable to the Middle Eocene. Namely, the Middle/Upper Eocene boundary would be indicated by the extinction of *Chiasmolithus grandis* (Braml. et Ried.)—a species regularly occurring throughout the sequence involved (boundary of NP zones 17 and 18). It is quite probable that even NP zone 17 representing the uppermost part of the Middle Eocene is absent for a considerable part, for the range of *Sphenolithus furcatoides* Loecher encounterable in the samples from below 7 m depth passes but into the lower part of NP zone 17.

Paleoenvironment

The formation evolves with a transitional subunit, but without any break in sedimentation, from the shallow-water carbonate platform facies sediments of the Szőc Formation, thus its lower part must still have been deposited close to the shallow-water platform, on a bottom that lay not very much deeper than that. The fine muddy sediment originated in a slightly agitated water, beneath the zone of wave action. The comparatively rich benthonic fauna *(Mollusca, Foraminifera, Brachiopoda, Bryozoa)* may have lived on a shallow sublittoral bottom more weakly penetrated by sunlight as compared to the case of the shallow-water platform.

Typical of the lower part of the formation, the enrichment of glauconite seems to have been connected with the volcanic activities—a probability referred to by the rather frequent presence of biotite as well.

Towards the upper part of the formation an increase in pelagicity and water depth is indicated by achieved predominance of planktonic fossils and, parallel to this, by the complete disappearance of the larger Foraminifera of the shallow-water platform environment. Consequently, the environment of deposition seems to have been a pelagic shelf area.

BIBLIOGRAPHY

Böckh J. 1874: A Bakony déli részének földtani viszonyai. I. — Ann. Inst. Geol. Publ. Hung. 2.

Dudich E. 1977: Eocene sedimentary formations and sedimentation in the Bakony Mountains, Transdanubia, Hungary. — Acta Geol. 21 (1–3).

Dudich E. 1978: A Bakony hegység eocén üledékföldtana. — Cand. D. Sc. dissertation. Manuscript.

Gidai L. 1977: A Sümeg–Csabrendek környéki eocén képződmények földtani alapszelvénye, a csabrendeki Cn-850. sz. fúrás alapján. (Coupe de référence géologique des formations éocène des environs de Sümeg et Csabrendek, d'après le sondage n° Cn-850.) — Rélations Ann. Inst. Geol. Hung. (1975).

Hantken M. 1874: Az Alveolinák szerepe a délnyugat-magyarországi hegység eocén képződményeiben. — Földt. Közl. 4.

Hantken M. 1875: A nummulitok rétegzeti (sztratigraphiai) jelentősége a délnyugati középmagyarországi hegység ó-harmadkori képződményeiben. — M. Tud. Akad. Ért. a Term. Tud. Köréből 5.

Hojnos R. 1943: Adatok Sümeg geológiájához. (Über die Eozaen und Kreidebildungen von Sümeg.) — Rélations Ann. Inst. Geol. Hung. (1939–40).

Jámbor Á.–Korpás L. 1971: A Dunántúli-középhegység kavicsképződményeinek rétegtani helyzete. (Stratigraphische Lage der Schotterbildungen im Transdanubischen Mittelgebirge.) — Rélations Ann. Inst. Geol. Hung. (1969).

Jámborné Kness M. 1971: Nagy-Foraminifera vizsgálatok a nagytárkányi Nt-1103. és a városlődi Vl-1. fúrások eocén rétegsorából. (Recherches des grands Foraminifères de la série éocène des sondages Nt-1103 de Nagytárkány et Vl-1 de Városlőd.) — Rélations. Ann. Inst. Geol. Hung. (1968).

Kecskeméti T.–Kopek G. 1960: A bakonyi eocén szintezése nagy-Foraminiferák alapján. (Gliederung des Bakonyer Eozäns auf Grund von Grossforaminiferen.) — Földt. Közl. 90.

KECSKEMÉTI T.–VÖRÖS A. 1975: Biostratigraphische und palaeoökologische Untersuchungen einer transgressiven Eozänen Schichtserie (Darvastó, Bakony-Gebirge). — Fragm. Min. Pal. 6.

KOPEK G. 1980: A Bakony hegység ÉK-i részének eocénje. [L'Éocène de la partie nord-orientale de la Montagne du Bakony (Transdanubie, Hongrie).] — Ann. Inst. Geol. Publ. Hung. 63 (1).

KOPEK G.–DUDICH E.–KECSKEMÉTI T. 1971: L'Eocène de la Montagne de Bakony. — Ann. Inst. Geol. Publ. Hung. 54 (4).

KOPEK G.–KECSKEMÉTI T. 1964: A bakonyi eocén kőszéntelepek keletkezési körülményeiről. (Über die Entstehungsbedingungen der eozänen Kohlenlargerstätten im Bakonygebirge.) — Földt. Közl. 94.

KOPEK G.–KECSKEMÉTI T.–DUDICH E. 1966: A Dunántúli-középhegység eocénjének rétegtani kérdései. (Stratigraphische Probleme des Eozäns im Transdanubischen Mittelgebirge.) — Rélations Ann. Inst. Geol. Hung. (1964).

POMEROL CH. 1973: Ére cénozoïque. — DOIN editeurs. Paris.

RÁKOSI L.–TÓTH K. 1980: Adatok a déli Bakony eocén képződményeinek lito- és biosztratigráfiájához. (Contribution à la litho- et biostratigraphie de l'Éocène au sud de la Montagne Bakony.) — Rélations Ann. Inst. Geol. Hung. (1968).

SZŐTS E. 1956: Magyarország eocén (paleogén) képződményei. [L'Éocène (Paléogène) de la Hongria.] — Geol. Hung. ser. Geol. 9.